Quantification of Aortic Regurgitation

ASE Review 2018
Boston

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And thanks to Dr. Roberto Lang

Disclosure

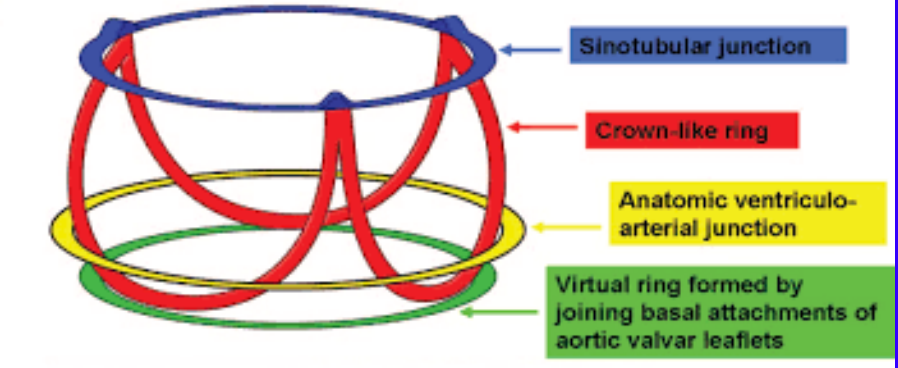
None related to this presentation

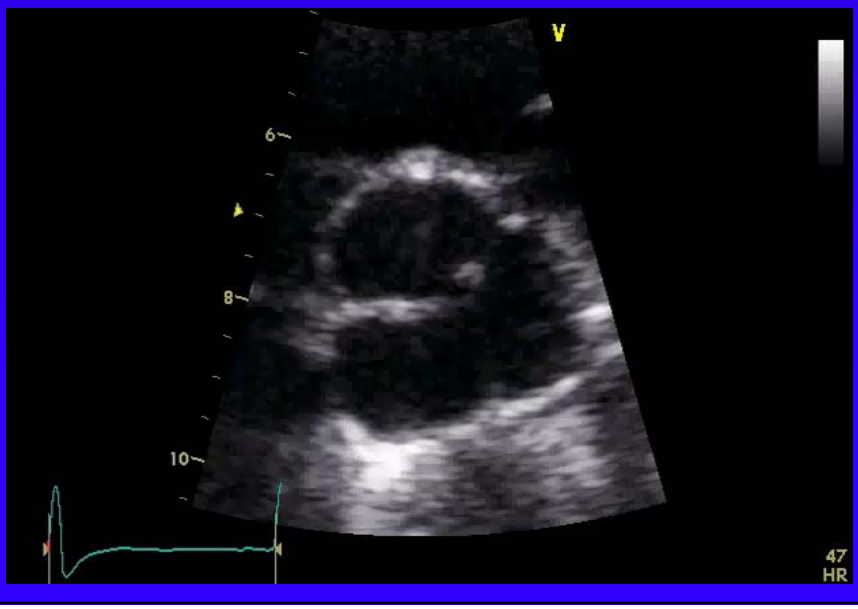
Objectives

- Anatomy
- Acute vs chronic
- Etiology
- Grading severity
  - Qualitative
  - Semiquantitative
  - Quantitative

- The cusps
- The aorta including
  - Sinuses of Valsalva
  - Sinotubular junction
- The aortomitral continuity
- The membranous septum

Valve cusps are not planar





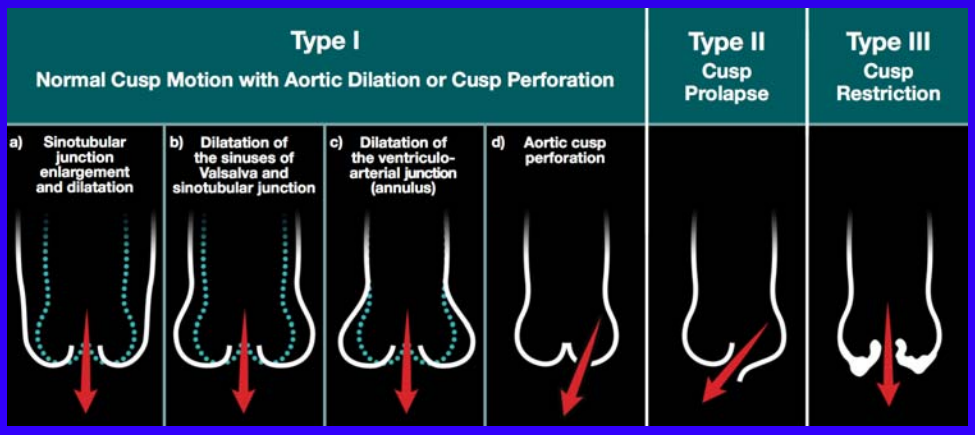
JASE April 2017

ASE GUIDELINES AND STANDARDS

Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation

A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance

William A. Zoghbi, MD, FASE (Chair), David Adams, RCS, RDCS, FASE, Robert O. Bonow, MD, Maurice Enriquez-Sarano, MD, Elyse Foster, MD, FASE, Paul A. Grayburn, MD, FASE, Rebecca T. Hahn, MD, FASE, Yuchi Han, MD, MMSc,* Judy Hung, MD, FASE, Roberto M. Lang, MD, FASE, Stephen H. Little, MD, FASE, Dipan J. Shah, MD, MMSc,* Stanton Shernan, MD, FASE, Paaladinesh Thavendiranathan, MD, MSc, FASE,* James D. Thomas, MD, FASE, and Neil J. Weissman, MD, FASE, *Houston and Dallas, Texas; Durham, North Carolina; Chicago, Illinois; Rochester, Minnesota; San Francisco, California; New York, New York; Philadelphia, Pennsylvania; Boston, Massachusetts; Toronto, Ontario, Canada; and Washington, DC*



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Abnormal Leaflets

- LEAFLET
  - CONGENITAL
    - Bicuspid, unicuspid, quadracuspid, VSD
  - ACQUIRED
    - Endocarditis, rheumatic disease, calcification, radiation, anorectic drugs

Abnormal aorta

- CONGENITAL
  - Bicuspid aortic valve, annuloaortic ectasia, CT disease
- ACQUIRED
  - HTN, SLE, Ankylosing spondylitis, dissection, syphilis
  - trauma

Acute severe

- LV not dilated
- Jet may appear small or not be visible
- EF likely to be reduced
- Early MV closure

Chronic severe

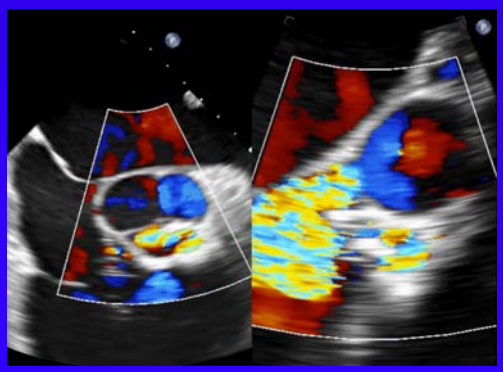
- LV dilated and globular
- Jet visible in all views
- EF may fall as late finding

Cause of Acute Severe Aortic Dissection

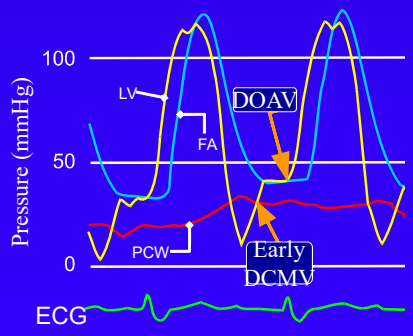
- Dissection with disruption of the valve commissures
- Endocarditis
- Chest trauma

Acute Aortic Regurgitation

69-year-old man admitted for sudden onset of severe shortness of breath with production of pink, frothy sputum



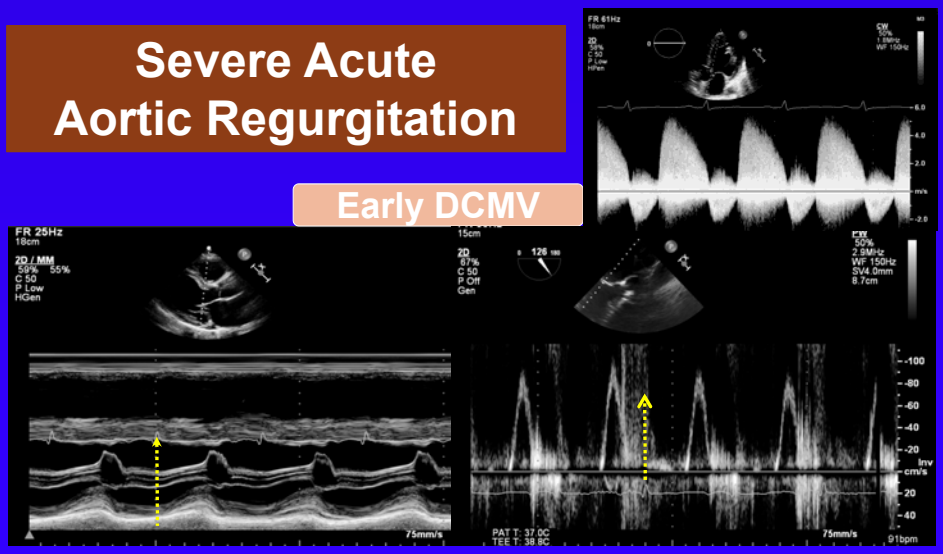
Acute Aortic Regurgitation



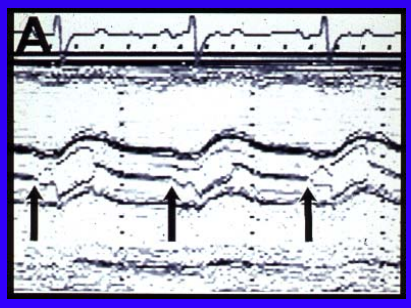
Early Diastolic Closure of the Mitral Valve
Diastolic Opening of the Aortic Valve

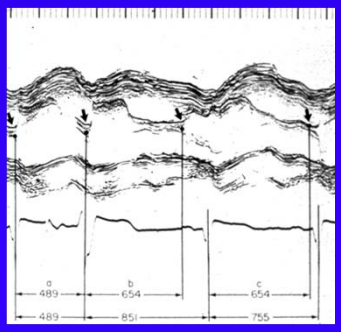
Severe Acute Aortic Regurgitation

Early DCMV

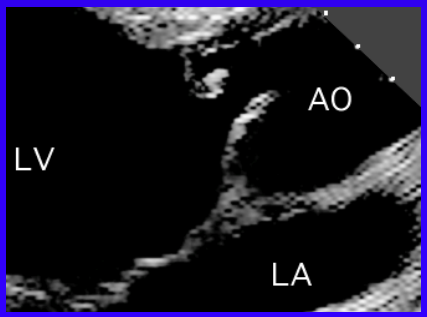


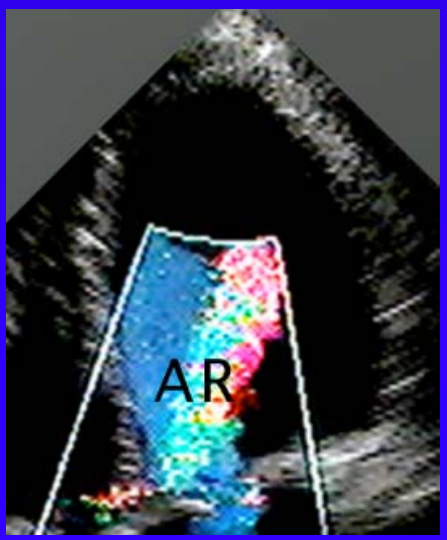
Diastolic Opening of the Aortic Valve





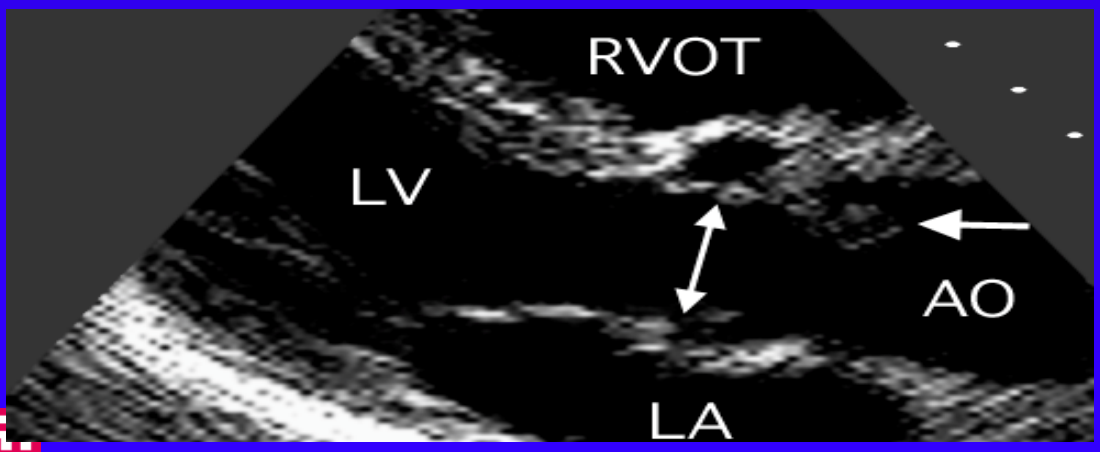
Meyer T et al., Am J Cardiol 1987;59:1144-1148



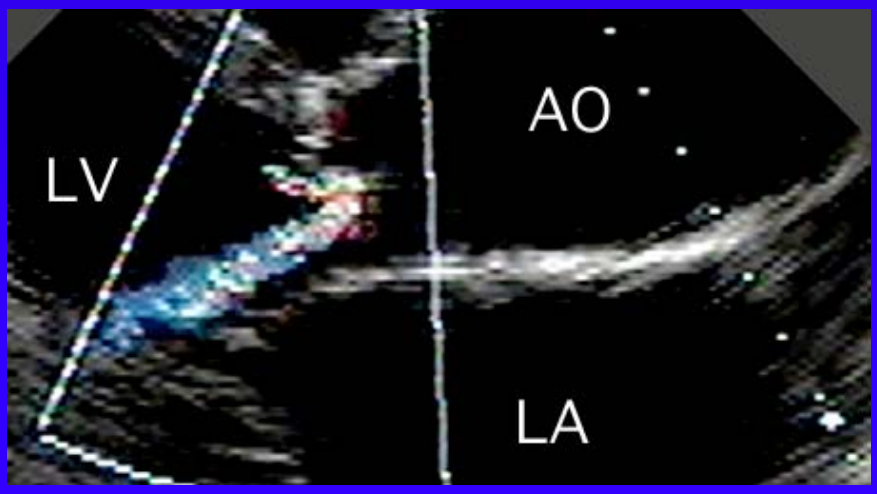


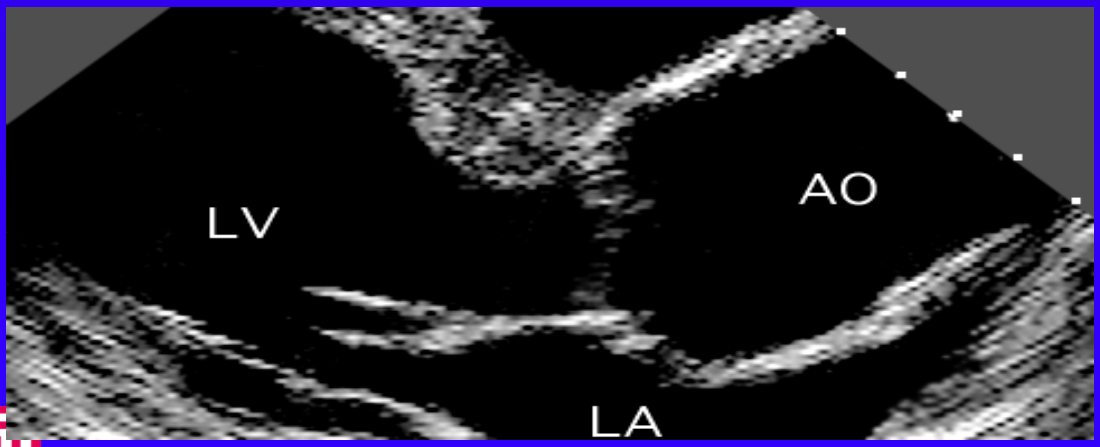
AR assessment

- What is the etiology
- What are the hemodynamic consequences
- How severe is the regurgitation

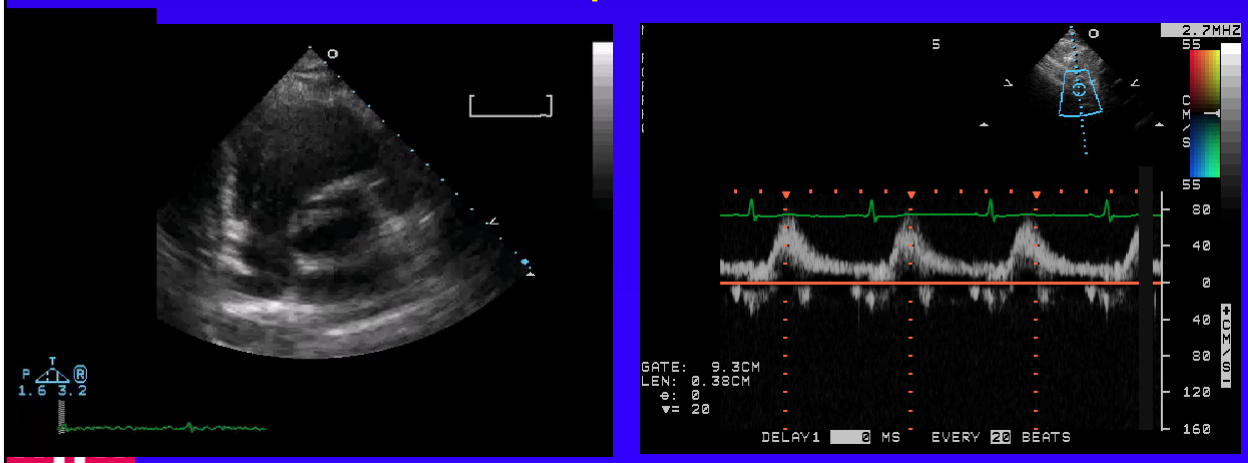


HTN most common cause of mild AR





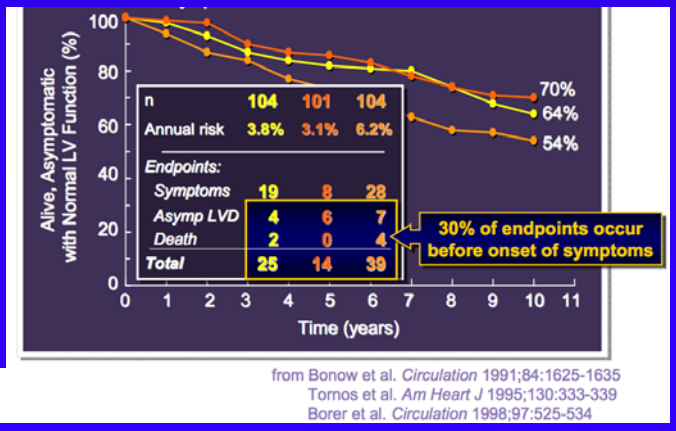
Etiology of Chronic AR is key to surgical plan



Grading the Severity of Chronic AR

- Structural parameters
- Qualitative Doppler parameters
- Semi-quantitative Doppler parameters
- Quantitative Echo-Doppler parameters

Natural History of Asymptomatic Patients with Severe AI and Normal LV Function



Courtesy

from Bonow et al. *Circulation* 1991;84:1625-1635
Tornos et al. *Am Heart J* 1995;130:333-339
Borer et al. *Circulation* 1998;97:525-534

Asymptomatic Severe AR with Normal LV Function

Rate of Progression to death, symptoms and LV Dysfunction

		Year	n	Rate
Bonow	*Circulation*	1984,1991	104	3.8%/yr
Scognomiglio	*Clin Card*	1986	30	2.1%/yr
Siemienczuk	*Ann Intern Med*	1989	50	4.0%/yr
Scognomiglio	*N Engl J Med*	1994	74	2.7%/yr
Tornos	*Am Heart J*	1995	105	3.0%/yr
Ishii	*Am J Cardiol*	1996	27	3.6%/yr
Borer	*Circulation*	1998	104	6.2%/yr
Tarasoutchi	*JACC*	2003	72	4.7%/yr
Evangelista	*N Engl J Med*	2005	31	3.6%/yr
Detaint	*JACC imaging*	2008	251	<5.0%/yr
Pizarro	*JACC*	2011	294	4.0%/yr
Total			113 8	4.2%/yr

Courtesy of Dr Bonow

Chronic AR generally evolves slowly with a long asymptomatic compensated phase

Grading the Severity of Chronic AR

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- **Structural parameters**
  - **Aortic leaflets**
  - **LV size**

Parameters	Mild	Moderate	Severe
Aortic leaflets	Normal or abnormal	Normal or abnormal	**Abnormal/flail, or wide coaptation defect**
LV size	**Normal**[2]	Normal or dilated	Usually dilated[3]

Grading the Severity of Chronic AR

- **Qualitative Doppler parameters**
  - **Jet width in LVOT**
  - **Flow convergence**
  - **Jet density, CW**
  - **Jet deceleration rate, CW (PHT,msec)**
  - **Diastolic flow reversal in descending AO, PW**

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Qualitative Doppler parameter

Jet Width/LVOT Diameter

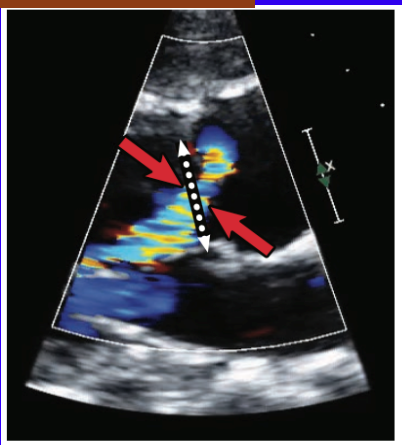
1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure jet (red arrows) in LVOT within 1cm of VC
4. Measure LVOT (white arrow)

Advantages:

- Simple sensitive screen for AR
- Rapid qualitative assessment

Disadvantages:

- Underestimates AR in eccentric jets
- May overestimate AR in central jets as AR jet may expand unpredictably below the orifice
- Affected by the size of the LVOT



Qualitative Doppler parameter

Proximal Flow Convergence

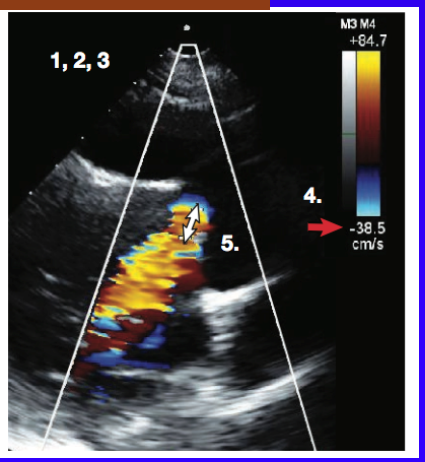
1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit (in direction of jet)
5. Measure radius (white arrow in image) from point of color aliasing to vena contracta

Advantage:

- Rapid qualitative assessment

Disadvantages:

- Multiple jets
- Constrained jet (aortic wall)
- Non-hemispheric shape
- Timing in early diastole



Qualitative Doppler parameter

Density of Regurgitant Jet

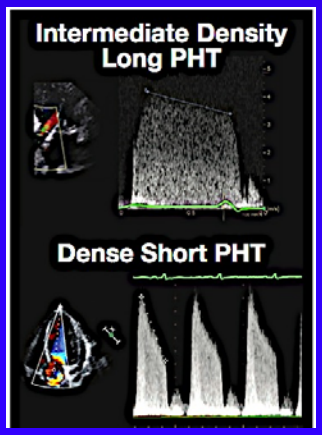
1. Align insonation beam with the flow
2. Adjust overall gain

Advantages:

- Simple
- Faint or incomplete jet is compatible with mild or trace AR

Disadvantages:

- Qualitative
- Perfectly central jets may appear denser than eccentric jets of higher severity
- Overlap between moderate and severe AR



Qualitative Doppler parameter

Jet Deceleration Rate (Pressure Half-time)

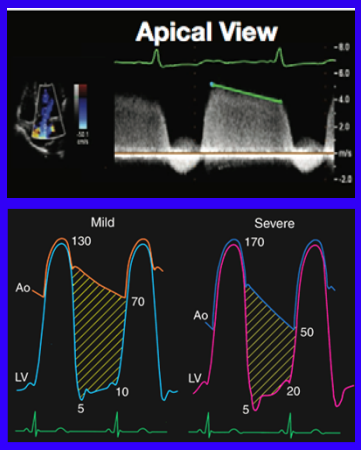
1. Align insonation beam with the flow
2. Usually best from apical windows
3. In eccentric jets, may be best from parasternal window, helped by color Doppler

Advantage:

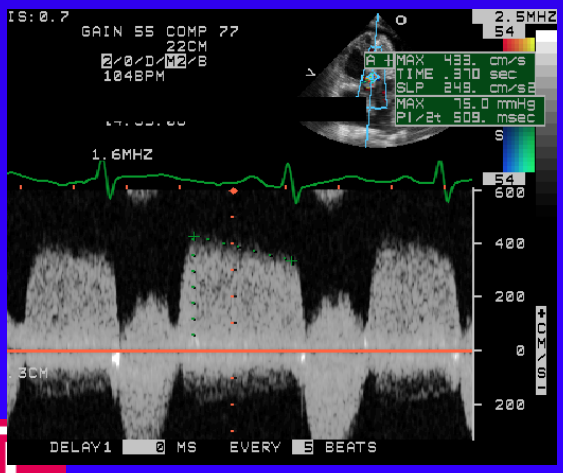
- Simple
- Specific sign of pressure relation between Ao and LV

Disadvantage:

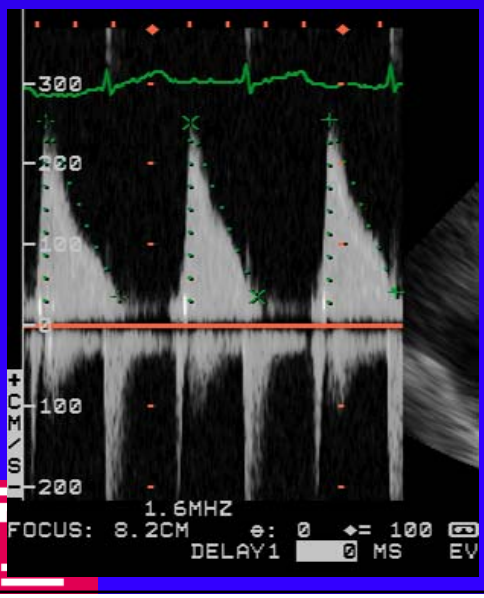
- Qualitative
- Poor alignment of Doppler beam may result in lower PHT
- Affected by changes that modify LV-Ao pressure gradient (If short, implies significant AR or high LV filling pressure)



Decel slope vs PHT



- PHT - msec
  - Mild - > 500
  - Moderate – 500-200
  - Severe < 200
- Decel slope – cm/sec
  - Mild - < 200
  - Moderate – 200 - 300
  - Severe >300



- PHT here is 130 msec
- Peal velocity ?
- Disadvantage of PHT method is that detecting peak velocity is key
- Easy in Mitral inflow
- Tougher in AR

Qualitative Doppler parameter

Holodiastolic Flow Reversal in Proximal Descending Aorta

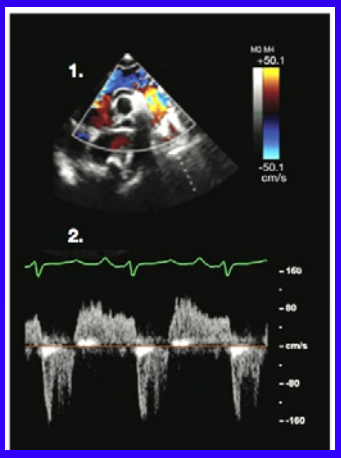
1. Align insonation beam with the flow
2. Pulsed sample volume in the proximal descending or abdominal aorta

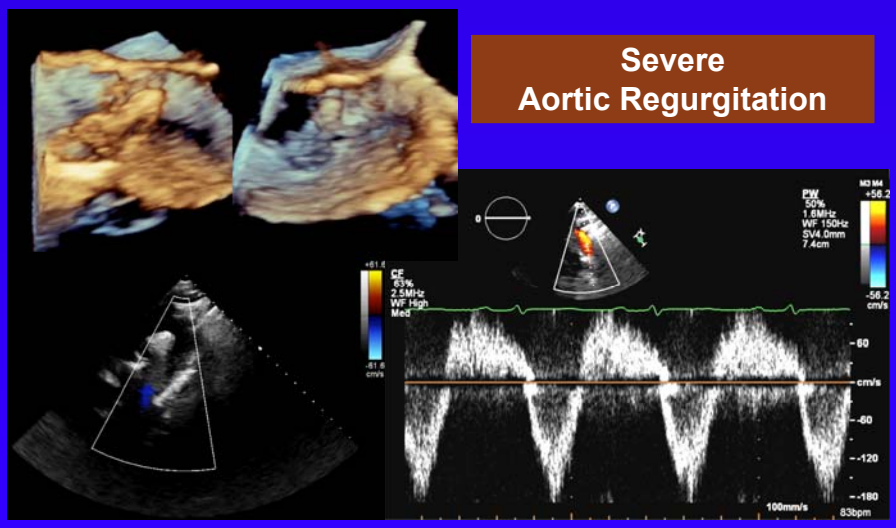
Advantages:

- Simple supportive sign of severe AR
- More specific sign if seen in abdominal aorta

Disadvantages:

- Depends on compliance of the aorta; less reliable in older patients
- Brief velocity reversal is normal
- May be seen in other conditions
- May not be holosystolic in acute AR





Severe Aortic Regurgitation

Grading the Severity of Chronic AR
Qualitative Parameters

Parameters	Mild	Moderate	Severe
Qualitative Doppler			
Jet width in LVOT, color flow	**Small in central jets**	Intermediate	**Large in central jets;** variable in eccentric jets
Flow convergence, color flow	**None or very small**	Intermediate	**Large**
Jet density, CW	**Incomplete or faint**	Dense	Dense
Jet deceleration rate, CW (PHT, msec)[4]	Incomplete or faint, Slow >500	Medium 500-200	**Steep <200**
Diastolic flow reversal in descending aorta, PW	**Brief, early diastolic reversal**	Intermediate	**Prominent holodiastolic reversal**

Grading the Severity of Chronic AR

- **Semiquantitative parameters**
  - **VCW (cm)**
  - **Jet width/LVOT width, central jets (%)**
    - **Jet CSA/LVOT CSA, central jets (%)**

Semi-quantitative parameter

Vena Contracta

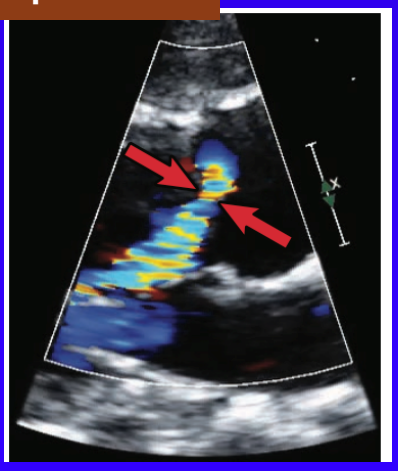
1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure the narrowest jet diameter at or just apical to the valve

Advantages:

- Surrogate for regurgitant orifice size
- May be used in eccentric jets
- Independent of flow rate and driving pressure
- Less dependent on technical factors
- Good at identifying mild or severe AR

Disadvantages:

- Presence of multiple jets or bicuspid valves
- Convergence zone needs to be visualized
- The direction of the jet will influence its appearance



Semi-quantitative parameter

3D Color Doppler

3D Vena Contracta

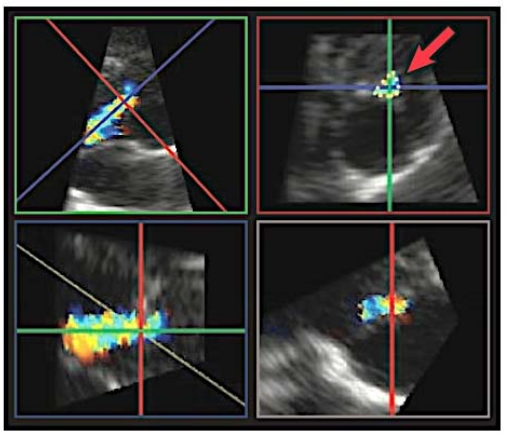
1. Color flow sector should be narrow
2. Align orthogonal cropping planes along the axis of the jet
3. Choose a mid-diastolic cycle
4. Non-coaxial jets or aliased flow may appear "laminar" but still represent regurgitant flow

Advantage:

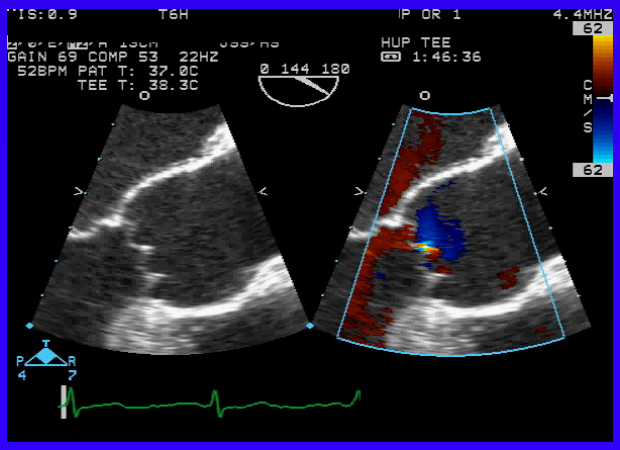
- Multiple jets of differing directions may be measured

Disadvantage:

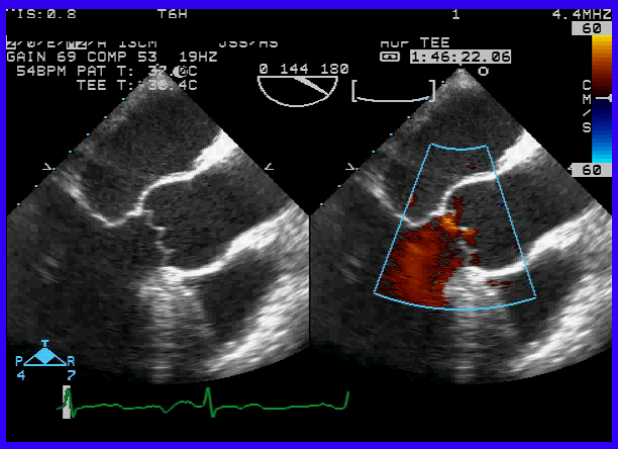
- Dynamic jets may be over- or underestimated



How severe is this AR?



How about now? Explanation



Semi-quantitative parameter

Jet Area/LVOT Area

1. Short-axis, zoom view
2. Measure in LVOT within 1 cm of the VC)

Advantage:

- Estimate of regurgitant orifice area

Disadvantages:

- Direction and shape of jet may overestimate or underestimate jet area

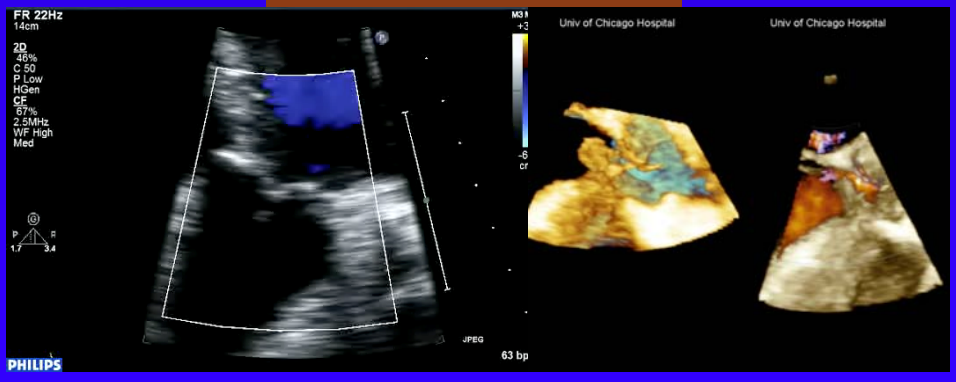
Grading the Severity of Chronic AR
Semi-Quantitative Parameters

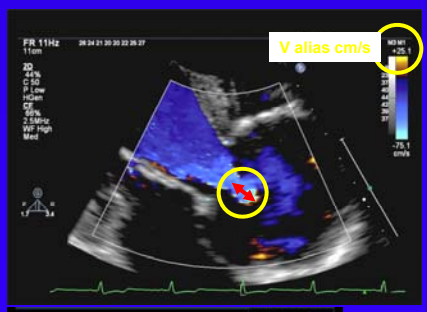
Parameters	Mild	Moderate		Severe
VCW (cm)	<0.3	0.3-0.6		>0.6
Jet width/LVOT width, central jets (%)	<25	25-45	46-64	≥65
Jet CSA/LVOT CSA, central jets (%)	<5	5-20	21-59	≥60

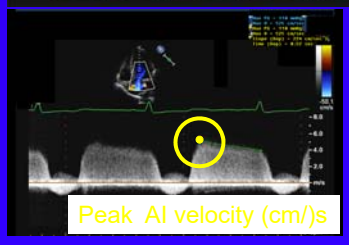
Grading the Severity of Chronic AR

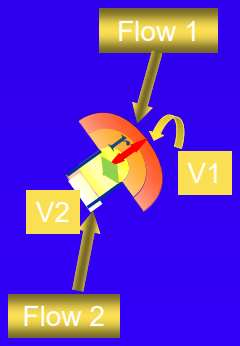
- **Quantitative parameters**
  - **RVol (ml/beat)**
  - **RF**
  - **EROA (cm^2)**

Quantitative parameter







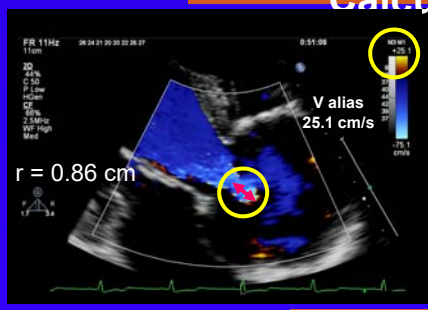


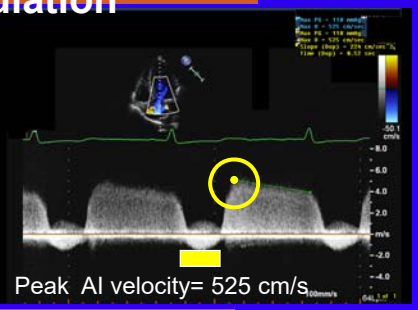
$Q_{prox} = Q_{distal}$

$A_1 V_1 = A_2 V_2$

$(2\pi r^2) \times Va = EROA \times Vjet$

Flow Convergence Calculation





$(2\pi r^2) \times V_{alias} = EROA \times V_{AI}$

$6.28\ (.86)^2 \times 25.1 = EROA \times 525$

$116.6 = EROA \times 525$

$116.6/525 = .22\ cm^2 = EROA$

Quantitative parameter

Flow Convergence Method (PISA)

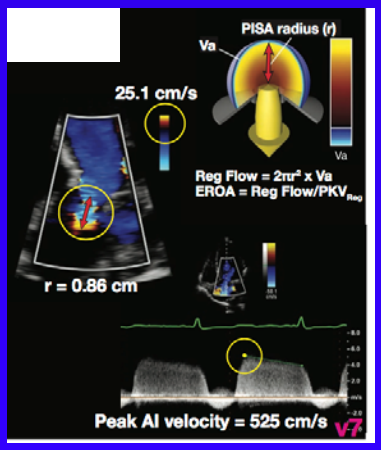
1. Align insonation beam with the flow
2. Lower the color Doppler baseline in the direction of the jet
3. Look for the hemispheric shape to guide the best lower Nyquist limit
4. CW Doppler of regurgitant jet for peak velocity and VTI

Advantage:

- Rapid quantitative assessment of lesion severity (EROA) and volume overload (R Vol)

Disadvantages:

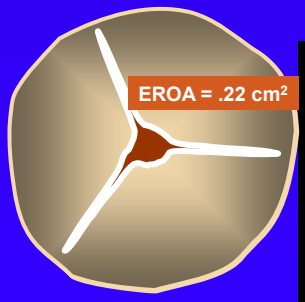
- Feasibility is limited by aortic valve calcifications
- Not valid for multiple jets, less accurate in eccentric jets
- Small errors in radius measurement can lead to substantial errors in EROA

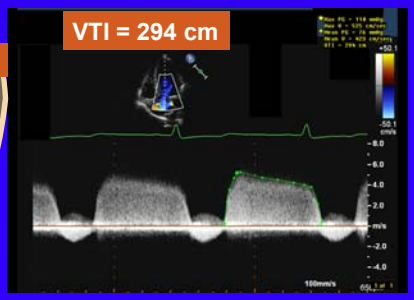


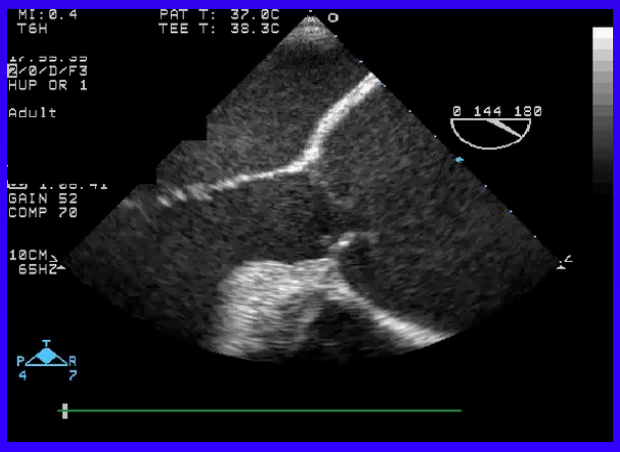
Regurgitant Volume

EROA x VTI AI

RVOL= 0.22 x 294 = 65cc



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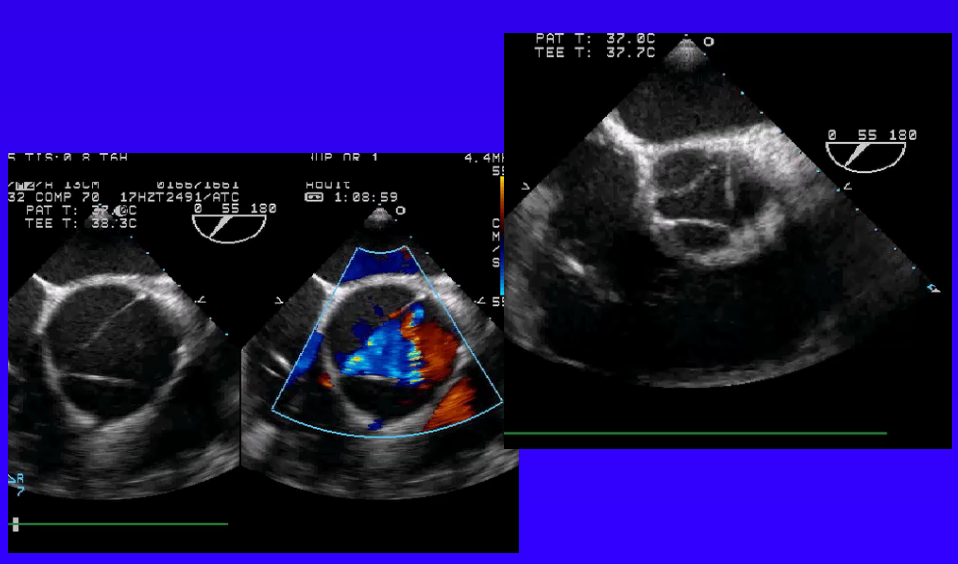
T6H
PAT T: 37.0C
TEE T: 38.3C
HUP OR 1
Adult
0 144 180
GAIN 52
COMP 70
10CM
65HZ


PAT T: 37.0C
TEE T: 37.7C
0 55 180
COMP 70
PAT T:
TEE T: 38.3C
1:08:59

Regurgitant Volume

- Mild <30 cc
- Mild-moderate 30-44 cc
- Moderate 45-59 cc
- Severe ≥ 60 cc

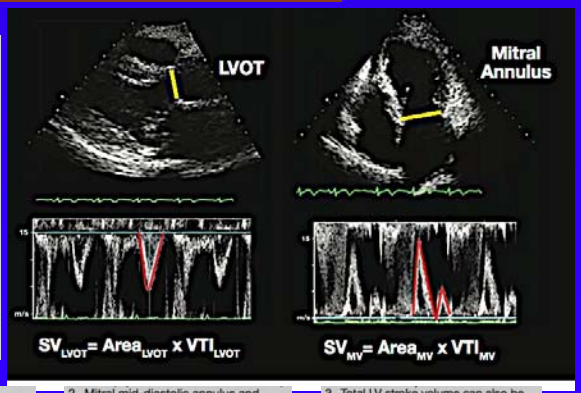
Quantitative parameter

Advantages:

- Quantitative, valid with multiple jets, eccentric jets
- Provides both lesion severity (EROA, RF) and volume overload (RVol)

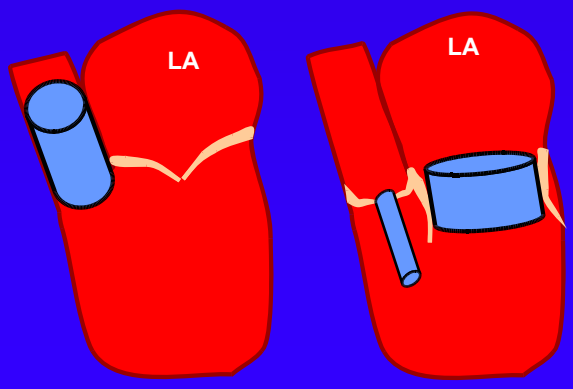
Disadvantages:

- Difficulties measuring mitral annulus diameter,
- In setting of MR, pulmonic stroke volume used for forward stroke volume
- Cumbersome, needs training
- Small errors in diameter measurement can lead to substantial errors in EROA



1. LVOT systolic diameter and pulsed Doppler sample volume from different views but at same anatomic level (represents total stroke volume)
2. Mitral mid-diastolic annulus and pulsed Doppler at the same annulus from apical view (represents forward stroke volume)
3. Total LV stroke volume can also be measured by the difference between LV end-diastolic volume and end-systolic volume (best by 3D)

Regurgitant Volume = SV Ao – SV MV



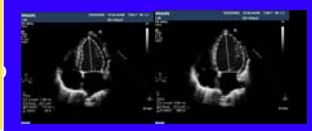
Regurgitant Fraction

$$RF\ \% = \frac{\text{AR regurg. volume (cc)}}{\text{Ao stroke volume (cc)}} \times 100$$

$$= \frac{65\ cc}{89\ cc} \times 100$$

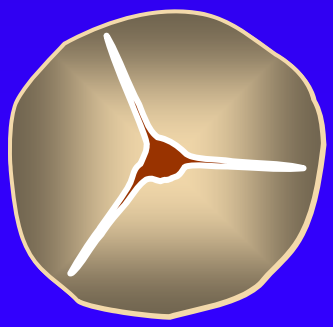
RF = %

- <30
- 30 -39
- 40 – 49
- >50

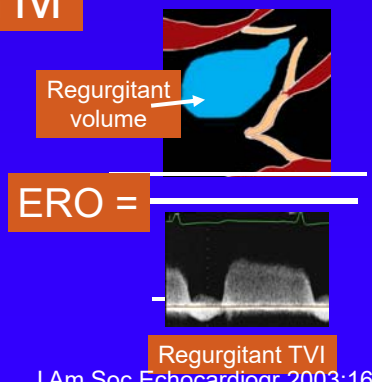


Effective Regurgitant Orifice Area

Reg Vol = ERO x REG TVI
ERO = REG Vol / Reg TVI



ERO



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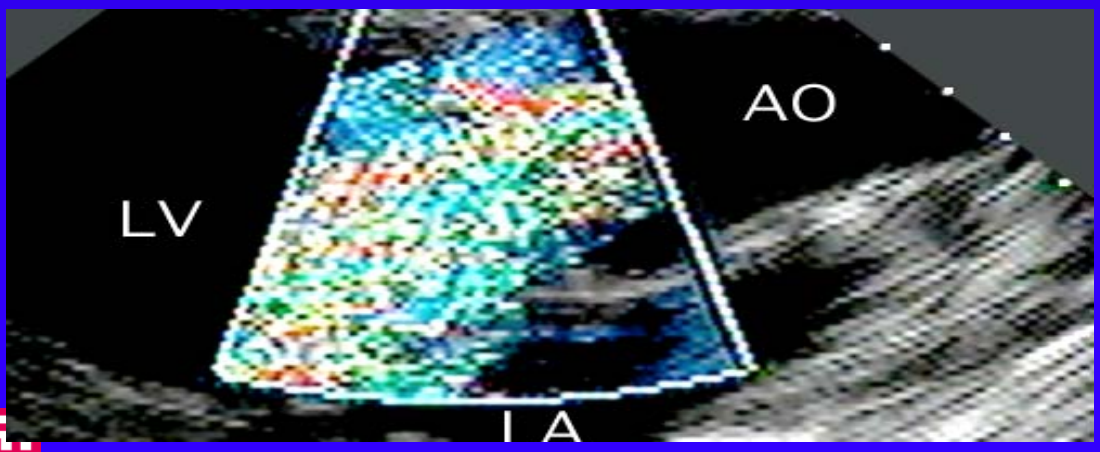
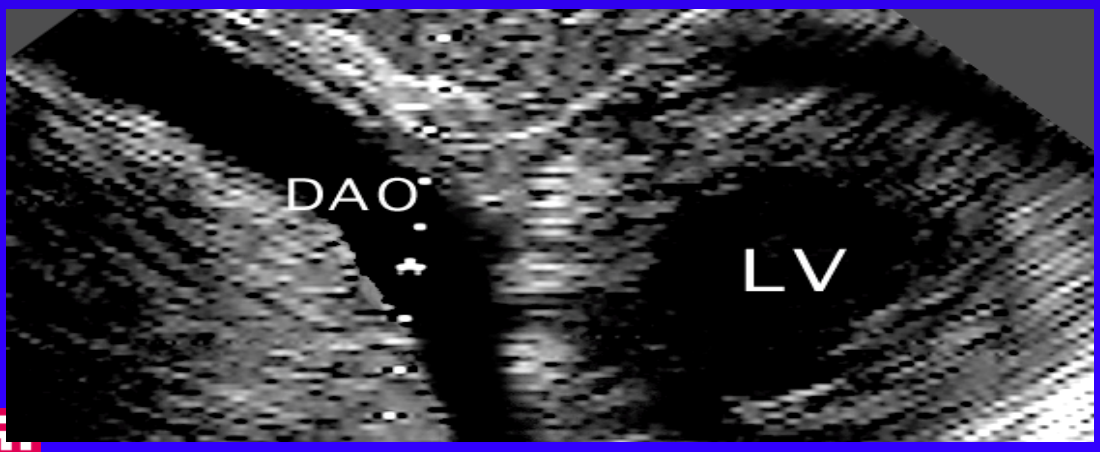
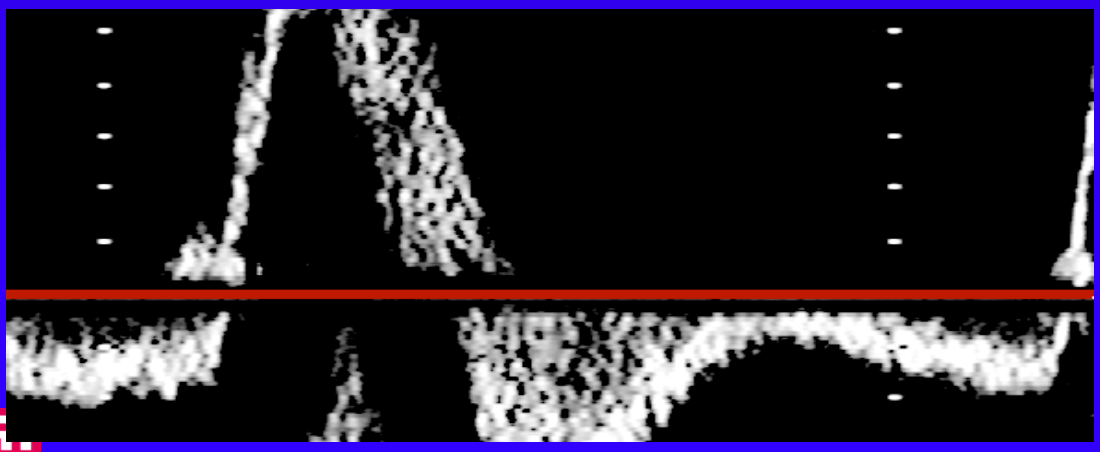
Grading the Severity of Chronic AR
Quantitative Parameters

Parameters	Mild	Moderate		Severe
RVol (mL/beat)	<30	30-44	45-59	≥60
RF	<30%	30-39%	40-49%	≥50%
EROA (cm^2)	<0.10	0.10-0.19	0.20-0.29	≥0.30


AO
LV
LA


DAO
LV

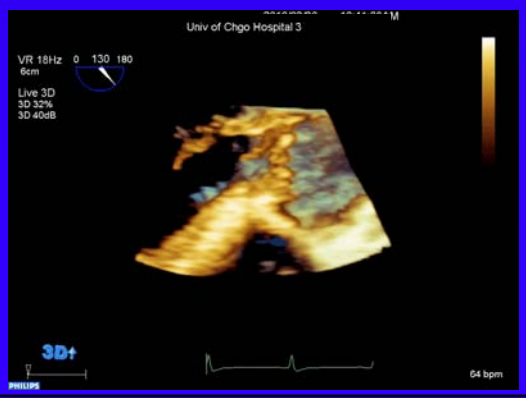


When to Perform CMR or TEE

- Poor TTE quality or low confidence in measured Doppler parameters
- Discordant quantitative and qualitative parameters and/or clinical data

→ **Indeterminate AR**
Consider further testing:
TEE or CMR for quantitation

*Beware of limitations of color flow assessment in eccentric AR jets; volumetric quantitation and integration of other parameters is advised



Conclusions

- Establishing the size of the ventricle and aorta of key importance
- Serial echoes in asymptomatic severe (or suspected severe) AR meet appropriate use criteria for echo
- Be prepared for discrepant indices

Thank you for your attention